

Constraints on model atmospheres from complex asteroseismology of the β Cephei stars

Szewczuk Wojciech, Walczak Przemysław and Daszyńska-Daszkiewicz Jadwiga

Abstract Using the method termed complex asteroseismology, we derive constraints on model atmospheres, in particular, on the NLTE effects. We fit simultaneously pulsational frequencies and the corresponding values of the nonadiabatic complex parameter f for the four β Cephei stars: θ Oph, ν Eri, γ Peg and 12 Lac. The LTE Kurucz models and the BSTAR2006 NLTE models are tested.

1 Complex asteroseismology

We compute seismic models which fit centroid frequencies for different values of mass, chemical composition and the core overshooting parameter. From this set of models we choose those which reproduce the nonadiabatic parameter f using the method of [3]. The f -parameter describes the ratio of the bolometric flux perturbation to the radial displacement at the photosphere level and its theoretical values are obtained from linear nonadiabatic theory of stellar pulsation. All computations were obtained with the OPAL opacities. Two chemical mixtures were adopted: A04 ([1]) for ν Eri and θ Oph, and AGSS09 ([2]) for 12 Lac and γ Peg. The empirical values of f were determined with the LTE Kurucz ([4]) models and the NLTE model atmospheres ([5]). Two values of the microturbulent velocity, ξ_t , were considered.

2 Constraints on model atmospheres

The empirical values of the nonadiabatic f -parameter of the β Cep stars are sensitive to the model atmospheres ([3]). In the case of 12 Lac and γ Peg, the values of f

Szewczuk W., Walczak P., Daszyńska-Daszkiewicz J.
Instytut Astronomiczny, Uniwersytet Wrocławski, Kopernika 11, 51-622 Wrocław, Poland, e-mail:
szewczuk@astro.uni.wroc.pl, walczak@astro.uni.wroc.pl, daszynska@astro.uni.wroc.pl

obtained with the NLTE models reproduce the theoretical counterparts corresponding to seismic models with lower values of α_{ov} . For 12 Lac, the minimum of χ^2 , as results from fitting the photometric amplitudes and phases, occurs for the NLTE atmospheres (see Table 1). In the case of ν Eri and γ Peg, the minimum of χ^2 is reached for the LTE models with the microturbulent velocity of $\xi_t=8$ km/s. On the other hand, for ν Eri the error box of the f -parameter for two dominant frequencies calculated with the NLTE models encloses more seismic models than with the LTE ones. We did not get any preference of model atmospheres for θ Oph, most probably because of the least accurate data. In Table 1 we give the empirical values of f at the minimum of χ^2 for the dominant modes of the four studied stars. These values were determined for various model atmospheres.

Table 1 The empirical values of f for dominate modes at the minimum of χ^2 . For each star calculations were performed for the central values of the observational error box. Model of atmospheres are coded the same as in Kurucz [4] and Lanz & Hubeny [5].

freq [c/d]	f_R	f_I	ℓ	χ^2	atm	freq [c/d]	f_R	f_I	ℓ	χ^2	atm
12 Lac						γ Peg					
5.1790	-8.66±0.38	-1.28±0.38	1	12.9	BGv2	6.5897	-8.58±0.11	1.28±0.11	0	5.84	BGv2
	-9.17±0.45	-1.32±0.45		16.1	Kp00k2		-8.89±0.09	1.31±0.09		3.9	Kp00k2
	-9.53±0.66	-1.38±0.66		31.5	Kp00k8		-8.84±0.06	1.28±0.06		1.5	Kp00k8
ν Eri						θ Oph					
5.7633	-8.88±0.39	0.75±0.40	0	59.1	BGv2	7.1160	-11.16±2.18	1.45±2.22	2	3.5	BGv2
	-9.24±0.37	0.76±0.38		50.7	Kp00k2		-12.31±2.42	1.58±2.46		3.6	Kp00k2
	-9.30±0.20	0.75±0.21		14.4	Kp00k8		-12.90±2.61	1.67±2.65		3.7	Kp00k8

3 Conclusions

There is a prospect for deriving constraints on model atmospheres from complex asteroseismology of the β Cephei stars. We got some for ν Eri, 12 Lac and γ Peg. In the case of θ Oph, more accurate data are needed. Moreover, to achieve a better consistency between theory and observations, models of stellar atmospheres have to be still developed and computed in more detail.

References

1. Asplund M., Grevesse N., Sauval A. J., Allende Pieto C., Kisleman D., 2004, A&A, 417, 751
2. Asplund M., Grevesse N., Sauval A. J., Scott P., 2009, ARA&A 47, 481
3. Daszyńska-Daszkiewicz J., Dziembowski W. A., Pamyatnykh A. A., 2003, A&A, 407, 999
4. Kurucz R., L., 2004, <http://kurucz.harvard.edu>
5. Lanz T., Hubeny I., 2007, ApJS, 169, 83